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## AM BROADCAST MEASUREMENTS USING THE SPECTRUM ANALYZER



# **AM Broadcast Measurements Using the Spectrum Analyzer**

by Clifford B. Schrock

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### **Acknowledgements**

The author thanks those in the F.C.C. Western Regional Offices who offered comments and suggestions, those in the networks who reviewed and edited the manuscript, Tom Cauthers of Collins Radio, and the personnel of KPAM-KLSC, KXL, and KRDR, for their patience.

Cover photo courtesy of KPAM-KLSC, Portland, Oregon.

# Equipment Performance Measurements

## I. Introduction

A broadcasting engineer typically makes three kinds of measurements: equipment performance measurements once a year, monitoring or continuous measurements, and day-to-day maintenance measurements. The primary criteria of the minimum standards set by the F.C.C. are to insure that the station operates in a manner that will not interfere with other stations, and also insure that a station will emit signals that produce good quality sound.

However, the radio business today is highly sophisticated. The "sound" is the most important product, and, to achieve that top rating, the equipment must be technically capable of the highest performance. The stringent market and "sound" requirements of modern radio can no longer be casually handled with 20-year-old equipment and measurement techniques. The F.C.C. standards are only a small starting point. The successful stations do much more: monthly proofs, studio proofs, and meticulous day-to-day maintenance.

Tektronix has compiled this procedures book to satisfy some of the demands of the broadcast industry. We have introduced a modern new product to the radio engineer, the low frequency or audio spectrum analyzer, and coupled this instrument with some of the most powerful diagnostic tests one could devise.

All equipment performance measurement requirements (§73.47) are covered along with monitoring and day-to-day tests. Included are techniques to increase the speed of testing so that you can perform more tests. Also, many new topics vital to the modern station, such as **tim** distortion in transmitters and positive peak modulating characteristics and distortion, are covered.

We must, however, offer this warning: if you are only interested in satisfying the F.C.C. rules—then this

booklet is not for you. The test equipment is laboratory grade and the procedures are relatively sophisticated. However, if you're seriously in the radio business, and are fighting for your rating (and your advertising dollars), then read on. You can't afford not to!

The Author

## II. Equipment Performance Measurements

Yearly equipment performance measurement tests are required by the F.C.C.<sup>1</sup> to demonstrate that a station is operating correctly. Some stations go beyond this requirement and do monthly tests or spot tests. However, time has always been a limiting factor when using conventional techniques (e.g., the point plot for frequency response).

We have taken the existing equipment performance measurement requirements and described new techniques for each measurement. Where possible, a measurement technique is also described that can be used directly—at **rf**, eliminating any nonlinearities produced by the monitor. These measurement techniques *far exceed* the intent of the existing F.C.C. rules. However, there are a couple of instances (each is noted) wherein the exact technique with which the measurement is made *does not* correspond to the F.C.C. rules. In those instances the engineer has the latitude to include descriptions, in the yearly proof, to prove that the new technique demonstrated good engineering practice (§73.46a) or verification may be made using standard techniques.

### A. Preparing for the Equipment Performance Measurement<sup>2</sup>

The accuracy of a proof depends upon the quality of the test equipment, and also the care with which it is connected, calibrated, and used. The sensitivity of the test instruments we are recommending demands the highest *good engineering practice* possible. And, not to be overlooked,

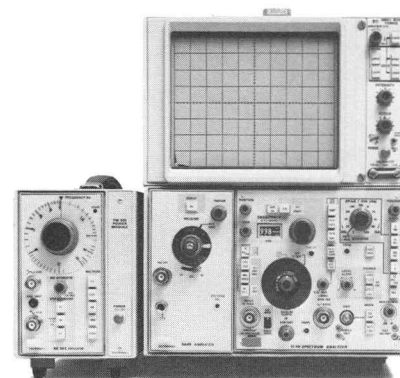


Fig. 1. 5L4N Low Frequency Analyzer and SG-502 Audio Generator

the station must also be in top shape, carefully connected and adjusted.

### Test Equipment Recommended

1. Low frequency Spectrum Analyzer, such as the 5L4N in an appropriate 5000-Series Main-frame.
2. Audio Generator, such as the SG 502.
3. Matching transformer, such as the W.E. 111C or the U.T.C. A-20.
4. Matching pad for the 5L4N input.
5. Miscellaneous patch cables.

### Other Applicable Equipment

1. Spectrum Analyzer, such as the 7L12 or the 7L5 (for alternate **rf** measurements).
2. Step Attenuator, 600 $\Omega$ , such as the Hewlett Packard model 405D.
3. Monopole antenna (see figure 18).
4. Vertical Amplifier, such as the 5A15 for the 5000-Series Main-frame.
5. Sampling loop antenna (see figure 6).

### Checking the Test Equipment

First, each piece of audio equipment should be checked to insure that the internal calibration is correct. The 5L4N has a detailed calibration procedure in the operating manual. An external 20 dB 600 $\Omega$  pad must be used ahead of the 5L4N input to extend the full screen measurement range from -10 dBm to +10 dBm. Details of the pad are shown in figure 2.

The audio generator should be connected through a matching trans-

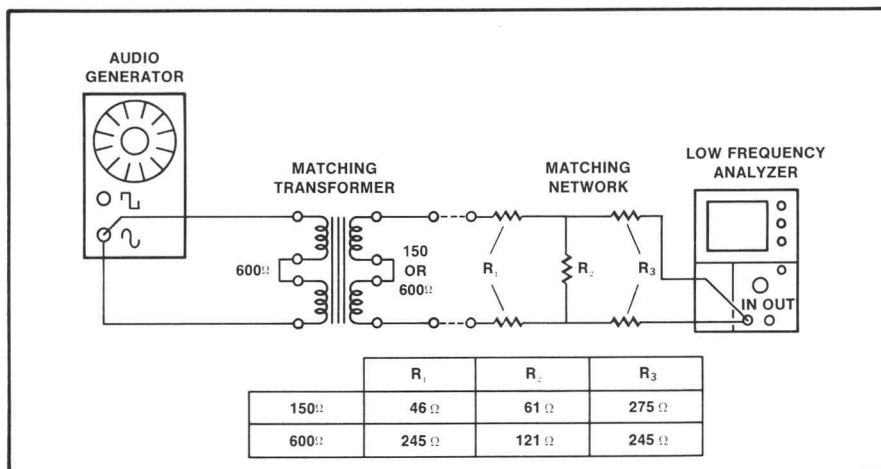


Fig. 2. Setup to Check the Test Equipment

former to the 5L4N as shown in figure 2. This transformer is necessary to insure noise- and hum-free low-level measurements.

1. Set the 5L4N to -10 dBm REF LEVEL, and select 600Ω INT TERM "ON."
2. Check the output level of the audio generator in the MAX position with all attenuation push-buttons OUT. The analyzer should indicate a full screen signal (+10 dBm through the 20 dB pad with the analyzer input attenuator set at -10 dBm).
3. Check for harmonic content of the generator by looking at a 0-to-20-kHz span on the analyzer. Tune the generator frequency from 20 Hz to 10 kHz and note that the harmonics (as shown in figure 3) are more than 70 dB down.
4. Check the flatness of the match-

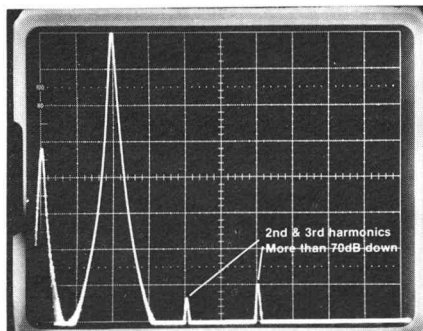


Fig. 3. Audio Generator Test for Harmonic Distortion

ing transformer by connecting the tracking generator output of the 5L4N instead of the audio generator. Ideally, it should be virtually flat from 20 Hz to 10 kHz. If it is not, note the error for future reference.

5. Finally, the generator should be reconnected, and the output level set to minimum with all attenu-

ation "IN." The baseline of the analyzer display should be clean and free of noise and spurious signals from 20 Hz to 20 kHz. This test should also be performed on location to insure that the transmitter is not interfering with the test equipment.

#### The Test Setup

The test points shown in figure 4 should be located at the station.<sup>3</sup> The 5L4N audio Spectrum Analyzer should be connected to the output of the modulation monitor or detector (B). The microphone input (A) to the main control room should also be accessible, preferably from the same point. The test equipment should be well grounded. Shielded cable should be used for all connections. If it is not practical to locate the generator and analyzer together (as in the case of remote transmitters), place the analyzer at the site of the modulation monitor and the generator in the main control room.

Signal processing equipment should be defeated although every attempt should be made to perform measurements with the equipment left in the processing chain. Most agc type equipment have built-in defeat switches that turn off the gain control loop without disturbing the signal path. Some engineers may patch out or bypass processing equipment. While this is not prohibited, it would be illegal to patch around any devices that purposely alter the frequency response (i.e., equalizers). This applies only to frequency altering devices normally used between the board output and transmitters.

#### Legal Requirements

F.C.C. rules (§73.93) require that the proof be performed by the holder of a first class license. Descriptions of the procedures used, equipment connections, and an equipment list are also required. All pertinent data such as equipment serial numbers, time of tests, persons who assisted, accuracy capability of test equipment, equipment removed or disabled, equipment connections, and personal recommendations or observations should all be incorporated into the final proof.

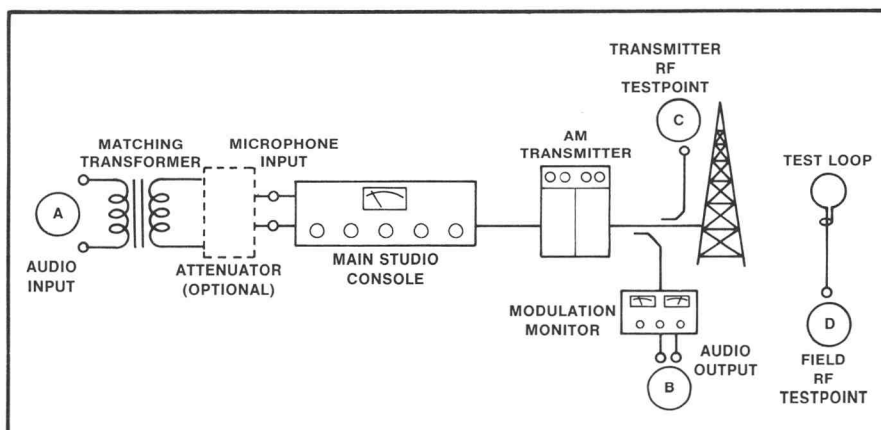


Fig. 4. Standard Test Points for Equipment Performance Tests

## B. Frequency Response

Frequency response is a measure of the transmitter's ability to pass a wide range of frequencies in the audio spectrum. The specification required by the F.C.C. (§73.40 [a-2]) calls for not more than  $\pm 2$  dB from the response level at 1000 Hz between 100 and 5000 Hz. In addition, it is required (§73.40 [A 12]) that emissions and spurious responses in the 15 to 30 kHz area from the carrier be at least 25 dB down from the unmodulated carrier. This requirement is generally satisfied by inserting a 10 kHz low pass filter at the audio input of the transmitter, thereby limiting the high frequency response of the transmitting system.

Two methods may be employed for response measurements. The audio response can be measured through a high quality **am** detector or monitor, using the low frequency spectrum analyzer such as the 5L4N, or the measurements can be made from the **rf** signal by using a high frequency spectrum analyzer such as the Tektronix 7L12 or 7L5. The **rf** measurement method eliminates the nonlinearities generated in the **am** detector or monitor and also discloses nonlinearities in the sideband response due to transmitter tuning, harmonic traps, and other line or antenna related defects.

### Procedure for Frequency Response Measurements at Audio

1. Connect the tracking generator output of the 5L4N to the microphone input (A) of the main studio console.
2. Connect the 5L4N analyzer input to the output (B) of an **am** detector or modulation monitor. A 20 dB pad should be used ahead of the 5L4N input to protect the input and establish a +10 dBm signal handling capability.
3. Set the analyzer for LOG span (20 Hz to 20 kHz), 600 $\Omega$  INPUT, INT LO Z, 2 dB/DIV, and SGL SWP mode.
4. Temporarily select the MNL SWEEP mode on the analyzer and position the spot to approximately 1000 Hz. Turn the input pot on the

console until the station modulation monitor (or oscilloscope) indicates 25% modulation. Switch to 100 ms/DIV and press the SWP button to sweep the analyzer and transmitter. Store the display or use a camera to record results.

5. Without erasing the display, repeat step 4 for modulation levels of 50%, 85%, and 100%. Results similar to figure 5 will be obtained.
6. Evaluate the photos by verifying that the deviation for each sweep from the level at 1 kHz is less than  $\pm 2$  dB ( $\pm 1$  division). The photo can serve as permanent record for your files.
7. Verify that the 10-kHz low pass filter is operating correctly by noting, in the response photo, that frequencies above 15 kHz are down at least 25 dB.

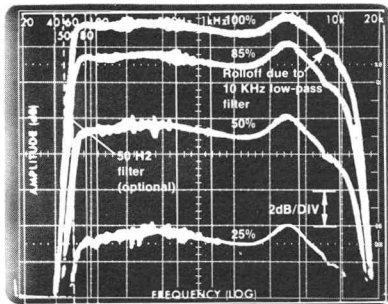


Fig. 5. Response Photo for 25%, 50%, 85%, and 100% Modulation

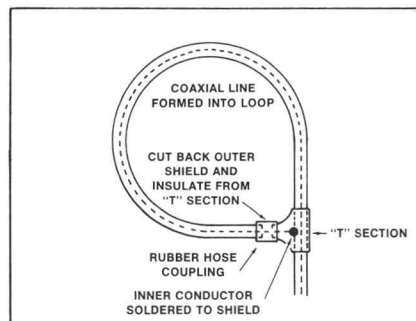


Fig. 6. How to Build a Sampling Loop

**NOTE:** The F.C.C. requires that a constant percentage of modulation be used for equipment performance measurements while the tests described measure the frequency response relative to the modulation at 1000 Hz. To satisfy yearly F.C.C. equipment performance measurement requirements (§73.47 a1), data

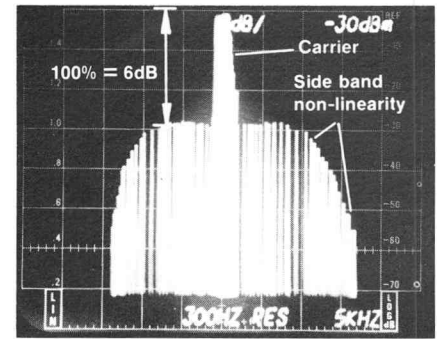


Fig. 7. Sideband Frequency Response at **rf** at 100% Modulation

should be obtained manually and recorded for 25%, 50%, 85%, and 100% modulation at the frequencies of 50, 100, 400, 1000, 5000 and 7500 Hz. The spectrum analyzer can still be used as the indicator, but the MNL mode should be used.

### Procedure for RF Frequency Response Measurements

**NOTE:** This procedure will not satisfy the present F.C.C. equipment performance measurements.

1. Connect a leveled audio generator (such as the SG 502) to the microphone input of the main studio console.
2. Connect the 7L12 or 7L5 Spectrum Analyzer to a sampling loop or test antenna. A simple loop<sup>4</sup> can be constructed from coax as shown in figure 6.
3. Tune the radio carrier being tested to center screen with the spectrum analyzer frequency controls. Select a span of 5 kHz/DIV and a resolution of 3 kHz. Use the 2-dB/DIV display mode.
4. Set the audio generator to 1 kHz and set the modulation level to 25%. This will be indicated by sidebands down 18 dB. This can be verified on the station modulation monitor.
5. Using storage, manually tune the generator from 50 Hz to 7.5 kHz. A display will be generated similar to figure 8.
6. Repeat steps 4 and 5 for modulation levels of 50% (12 dB down), 85% (7.4 dB down), and 100% (6 dB down).
7. If the upper and lower sideband

amplitudes do not match, a transmitter tuning problem that could cause response and distortion problems is indicated.

### C. Harmonic Distortion

Harmonic distortion or combined audio harmonics (§73.14a) is (are) the arithmetic sum of the amplitudes of all the separate harmonic components. This is the most common distortion test performed on transmitters and is measured by passing a pure sine-wave tone (at 1000 Hz for example) through a transmitter and measuring the sum of all the components (2000 Hz, 3000 Hz, 4000 Hz, etc).

The low frequency spectrum analyzer<sup>5</sup> presents a graphic display for analysis of the harmonics of the audio signal. This technique also makes it possible to observe noise and hum separately from distortion. The 5L4N, in combination with a good audio generator such as the SG 502, can make 70 dB (0.034%)

harmonic distortion measurements.

Harmonic distortion can also be measured directly at rf with a high quality spectrum analyzer such as the 7L12 or 7L5. This direct measurement eliminates errors that might occur in the traditional **am** detector or monitor that must be used for audio baseband measurements.

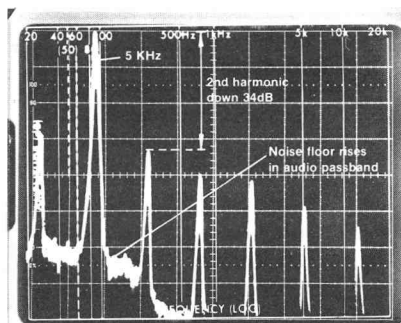


Fig. 9. Harmonic Distortion Display of 5 kHz Tone

### Procedure for Harmonic Distortion Measurements at Audio

1. Connect an audio generator (such as the SG 502) to the microphone input of the transmitter (A). Set the generator to 1000 Hz and, with the input fader set to mid-range, increase the generator output until 0 vu is indicated on the console.
2. Connect the low frequency spectrum analyzer to the monitor or diode detector test point (B). Set the analyzer controls to 10 dB/DIV, 1 kHz/DIV, and select a center frequency of 5 kHz. A display of the 1-kHz tone should be observed on the second graticule line from the left edge of the screen.
3. Set the generator output for an indication of 25% on the modulation monitor.

dB DIFFERENCE	ADD TO HIGHER LEVEL
Same (0dB)	3.01
1 dB	2.54
2	2.13
3	1.76
4	1.46
5	1.19
6	.97
7	.79
8	.64
9	.51

Fig. 8. Correction Factors for Addition of Components

RATIO in dB	% of READING	RATIO in dB	% of READING
20. (40:60)	10% (1% .1%)	30 (50:70)	3.16% (.31, .031%)
21	8.9	31	2.87
22	7.94	32	2.51
23	7.08	33	2.24
24	6.31	34	2.00
25	5.62	35	1.78
26	5.01	36	1.59
27	4.47	37	1.41
28	3.98	38	1.26
29	3.55	39	1.12

Fig. 10. dB to Percent of Distortion Chart

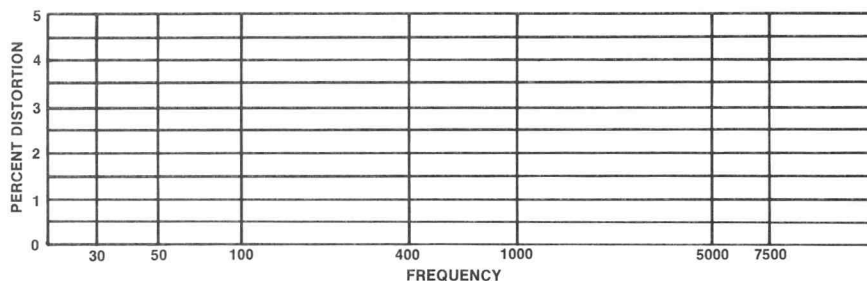


Fig. 11. Chart to Record Harmonic Distortion

4. Harmonic distortion may be measured by measuring the difference between the fundamental tone and the *sum* of the harmonics (second, third, fourth, etc).
5. The sum of the harmonics may be added using the chart in *figure 8*. Harmonics that are 10 dB or more down from the second do not have to be computed.
6. The difference between the fundamental and the harmonics may be measured in dB as shown in *figure 9*. These numbers may be converted to percentage of distortion using the chart in *figure 10*. Record the results on a chart such as the one shown in *figure 11*.
7. Repeat steps 3-6 for modulation levels of 50%, 85%, and 100%.
8. Repeat steps 3-7 for frequencies of 30, 50, 100, 400, 5000, and 7500 Hz.

#### Procedure for Harmonic Distortion Measurements at Rf

1. Connect an audio generator (such as the SG 502) to the microphone input of the transmitter (A). Set the generator to 1000 Hz and with the input fader set to mid-range, increase the generator output until 0 vu is indicated on the console.
2. Connect the 7L12 or 7L5 Spectrum Analyzer to a sampling loop (C) or test antenna (D) as shown in *figure 4*. Use 10 dB/DIV and select a span of 5 kHz/DIV, with the station carrier selected as the center frequency.
3. Adjust the generator output for an indication of 50% on the modulation monitor. This may be verified on the spectrum analyzer display by noting that 50% modulation will be indicated when the sidebands are down 12 dB.
4. Tune the transmitting frequency to center screen on the spectrum analyzer display and select a span of 1 kHz/DIV with 300-Hz resolution. Adjust the input attenuator until the carrier amplitude is displayed full screen. (The sampling loop or antenna may have

to be repositioned to obtain this level.) A display similar to *figure 12* should be obtained.

5. The difference between the fundamental and the sum of the upper or lower harmonics may be measured in dB as detailed in *figure 12* and converted to percentage of distortion using the chart in *figure 16*.
6. While this measurement is theoretically possible for any modulating frequency, the minimum resolution bandwidth of the 7L12 limits the lower frequency measurement to 500 Hz. The 7L5 can resolve distortion at rf on a 30-Hz tone and therefore may be used for the entire distortion test as specified by the F.C.C.

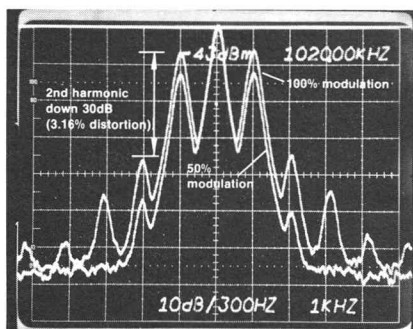


Fig. 12. Harmonic Distortion Measurements at rf for 50% and 100% Modulation

#### D. Percentage of Carrier Shift

Percentage of carrier shift is an indirect measurement of the transmitter ability to handle high modulation percentage without the power supply "sagging." It is a measure of power supply regulation. Carrier shift can also occur if rf power output tubes are weak or have insufficient grid drive.

A number of simple techniques have been used, including measurements directly off the line output meter incorporated into most transmitters. However, the rf spectrum analyzer may also be used to make this measurement very accurately.

With the advent of 125% positive peak modulation,<sup>6</sup> limited carrier shift in a positive direction may be encountered and is not in violation of the F.C.C. rules.

#### Procedure for Percent of Carrier Shift Using the Rf Measurement Spectrum Analyzer

*NOTE: Recheck the analyzer calibration.*

1. Connect a 400-Hz tone generator (SG 502) to the microphone input of the transmitter. Temporarily turn the generator output off.
2. Connect the 7L12/7L5 to a sampling loop or test antenna. With the station transmitter *on*, tune in the station on the analyzer using 10 dB/DIV. Then select 30-kHz resolution and the zero-span mode. Fine tuning of the analyzer will be necessary.
3. Adjust the input attenuator and gain until the horizontal line is within the top graticule area, then select the LIN mode. Fine tune the analyzer for maximum upward deflection of the display (horizontal line will be displayed), then, using the CAL variable knob on the attenuator (or the input attenuator on the 7L5), reset the horizontal line to the center horizontal graticule line. This is the zero modulation reference.
4. Adjust the generator for a 25% indication on the modulation monitor. This will also be indicated by a sine wave on the analyzer screen occupying two vertical divisions as shown in *figure 13*.
5. Use full video filtering to obtain a horizontal line. Any deflection of this line from the center is carrier shift. A shift of two minor divisions is equivalent to 5%. See *figure 14*.

*NOTE: The vertical sensitivity of this measurement may be increased to 1/4% per minor division (one minor division equals 0.25%) by using a vertical amplifier in the left vertical compartment of the mainframe connected to the VERT SIG OUT on the rear panel of the mainframe as shown in *figure 15*. Set the vertical gain to 20 mV/DIV.*

6. Repeat steps 3-5 for modulation levels of 50%, 85%, and 100%.

*NOTE: The 7L5 may be used for the*

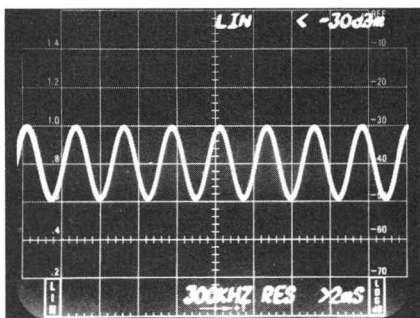


Fig. 13. Zero Span Display for Carrier Shift (25% Modulation)

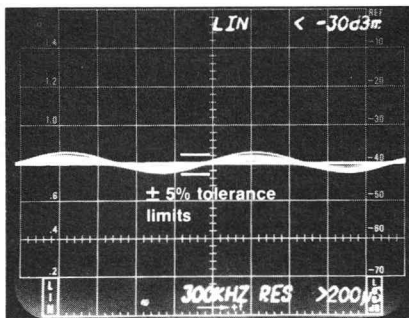


Fig. 14. Carrier Shift Measurement

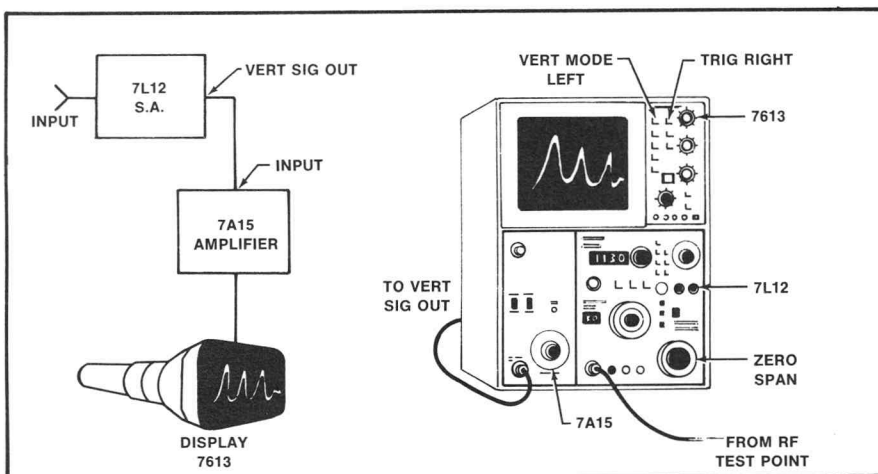


Fig. 15. Use of the VERT SIG OUT to Increase Measurement Sensitivity

measurement using a 10-Hz resolution bandwidth and a span of 1-kHz/DIV. No video averaging will be necessary because of the narrow resolution bandwidth.

## E. Carrier Hum and Noise

Carrier hum and noise measurements conventionally produce a number that represents the combinations of noise, low level spurs, hum, mechanical-to-electrical noise, etc. The exact amount of each type of noise is often difficult to determine, pinpoint, and correct. The use of the audio analyzer provides the dimension of frequency, making it possible to differentiate between hum, buzz, white noise, and low level spurious. The sensitivity of the measuring instrument ( $-145$  dBm at 10 Hz bw) makes it possible to probe through the entire signal chain and identify the defective stages.

A good exercise when making hum and noise tests is to rapidly go

through each signal source in the station (including the microphone) by potting each one up on the console and measuring the baseline. This test, in addition to helping find noisy inputs, will often identify low level spurs that can be traced to mechanical origins (such as air conditioner fans, pumps or tape drives, turntables, etc).

### Signal to Noise Procedures at Audio

1. Set up an audio generator (SG 502) at the microphone input of the main studio console (A). This generator will be used to establish a 100% modulation reference tone.
2. Connect the 5L4N low frequency Spectrum Analyzer to the detector or modulation monitor output (B). Select the 10-dB/DIV mode, 200 Hz/DIV, and a center frequency of 1000 Hz.
3. Set the microphone fader to mid-range. Using a 400-Hz tone, increase the generator output until

the vu meter on the console indicates 0 dB (100%), then verify that the station modulation monitor indicates 100%.

4. Select input attenuation on the low frequency analyzer so that the 400-Hz carrier is within the top 10 dB graticule on the analyzer screen. Adjust the variable input control knob until the carrier signal just touches the top graticule line. Use a slow sweep speed (100 ms/DIV) to insure that a narrow resolution bandwidth is automatically selected. Turn off the 400-Hz tone.
5. Slowly tune the analyzer to scan the frequency spectrum from 0 to 20 kHz. Search for hum components (60 Hz, 120 Hz, 180 Hz, etc), intermodulation components, and any other unusual signals. These components may be measured in dB down from the 400-Hz reference carrier (top graticule line). The F.C.C. specification (§73.40 a6) for combined total hum and noise must be at least 45 dB down from the 100% modulation reference tone.
6. Reset the analyzer controls for 1 kHz/DIV, and MANUALLY set the resolution bandwidth for the 3 kHz. Tune to a center frequency of 5 kHz. Turn on the Video Filter.
7. Signal to noise<sup>7</sup> ratio may be calculated by measuring the difference in dB between the 100% modulation reference (top graticule line) and the middle of the noise floor as shown in figure 16. Subtract a correction factor of 8.2 dB from the measured difference to obtain actual signal to noise.

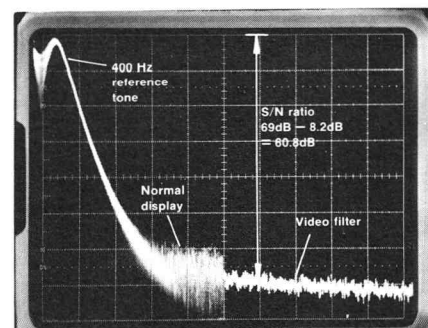


Fig. 16. Signal-to-Noise Measurements at Audio

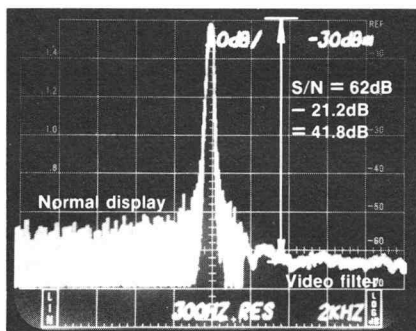
$$S/N_{\text{actual}} = S/N_{\text{measured}} - 8.2 \text{ dB bandwidth correction}$$

$$\text{Correction factor} = 20 \log \frac{\text{measured BW}}{\text{actual BW}} \text{ or } 20 \log \frac{3 \text{ kHz}}{20 \text{ kHz}} = 8.2 \text{ dB}$$

**NOTE:** The 3-kHz calibrated bandwidth precludes calibrated measurements below 5 kHz; however, the noise floor shape can be observed down to 50 Hz by manually selecting narrower resolution bandwidths.

#### Signal to Noise Procedure At Rf

1. Connect the 7L12 or the 7L5 Spectrum Analyzer to the rf test loop or test antenna. Select the 10 dB/DIV mode, 100 kHz span, and tune in the station carrier.
2. It is not necessary to use a reference tone for rf signal to noise measurements since the measurement is referenced to the station carrier and is equivalent to 100% modulation.
3. Adjust the input attenuator on the analyzer so that the carrier is within the top two graticule lines, then select 2 dB/DIV. Use the VAR CAL (red knob on the 7L12) to set the carrier to the top graticule line.
4. Decrease the SPAN/DIV to the narrowest span keeping the carrier centered with the tuning controls. Look for hum products and components or any other unusual carriers from -20 kHz to +20 kHz of the carrier. Note the relative levels of each of these components in dB down from the carrier. Any less than 45 dB down indicate that the performance tests for noise and hum is out of recommended tolerances.
5. Reset the analyzer SPAN/DIV to 2 kHz/DIV and select a resolution bandwidth of 300 Hz. Turn on all video filters. Note any non-symmetry of the noise floor around the carrier which may be due to transmitter tuning or other associated problems.
6. Signal-to-noise ratio can be calculated by measuring the difference in dB between the carrier reference (top graticule line) and the middle of the noise floor as shown in figure 17. Subtract a correction



**Fig. 17.** Signal-to-Noise Measurements at rf

factor of 21.2 dB from the measured difference.

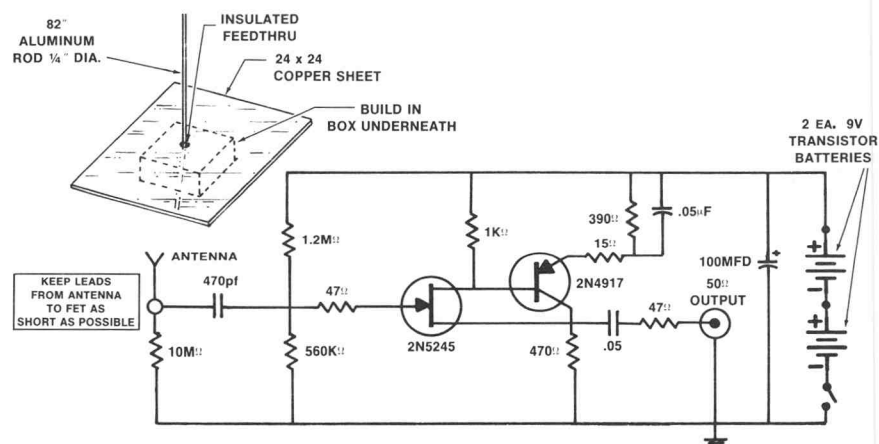
$$S/N_{\text{true}} = \frac{S/N_{\text{measured}}}{\text{bandwidth correction}} - 21.2 \text{ dB}$$

**NOTE:** The carrier can be safely driven off screen one 10 dB step so that a 61 dB measurement range is possible.

#### F. Spurious Signals and Harmonics

Spurious signal and harmonic measurements<sup>9</sup> are necessary to insure that there are no emissions from a transmitter that might potentially interfere with another radio service.

Measurements are usually performed at a distance of at least 1/4 mile from the antenna to insure that off-air emissions are accurately measured.



**Fig. 18.** Monopole Test Antenna and Construction Details<sup>9</sup> 100 kHz to 20 MHz

Poor feed line connections or corroded guy lines can cause the generation of spurious signals. While not presently required by the F.C.C., we relate all spurious and harmonic measurements to field strength in  $\mu\text{V}/\text{meter}$  at the frequency of the spurious component. Results presented in this manner are much more meaningful in terms of assessing the actual interference caused by a station.

Complete details on making field intensity measurements are on page 12 of this booklet.

#### Procedure for Measurement of Spurious Signals and Harmonic Emissions

1. Program material or a test tone should be used to modulate the transmitter to the greatest modulation percentage normally used. Program material is preferred.
2. With the 7L12 or 7L5 Spectrum Analyzer connected to a monopole test antenna (figure 18), search the area close to the carrier for spurious emissions. A systematic search at 5 kHz/DIV should be performed. Note any spurious emissions that are out of tolerance relative to the carrier (figure 20).
3. Using a span of 100 kHz/DIV, tune to the center of the broadcast spectrum (1050 kHz) or to the station carrier and identify each local station and any other carriers that may appear. Momentarily remove plate voltage on the transmitter to identify any sum and difference carriers that may

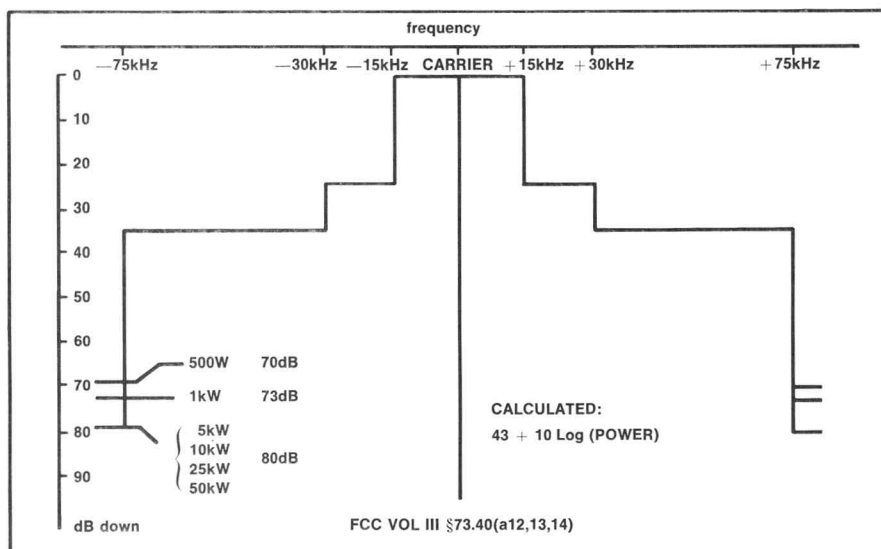


Fig. 19. Close-in Occupied Bandwidth Tolerance Chart

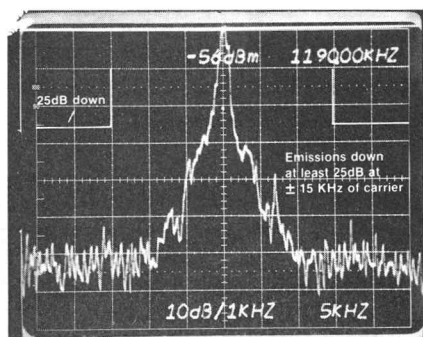


Fig. 20. Close-in Spurious Emission Check

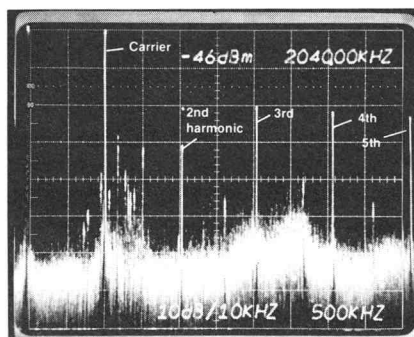


Fig. 22. Checking for Harmonics of the Carrier

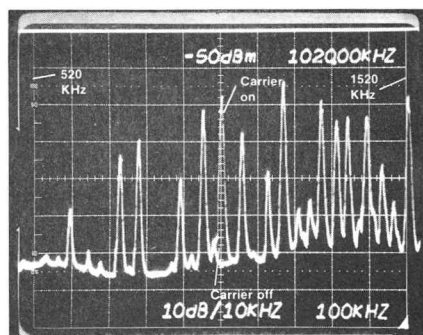


Fig. 21. Sum and Difference Beat Test—Dual Trace Display

exist. If there are no sum and difference beats with other stations, only the station carrier will disappear when plate voltage is dropped (figure 21).

4. Tune the second through tenth harmonics of the station carrier to insure that they are attenuated by at least  $43 + 10 \log (\text{POWER})$ . The difference in antenna correc-

tion factor should be subtracted from each harmonic measured to obtain actual differences in field strength for the harmonics measured. Actual values for standard power levels are shown in the chart in figure 19. Record results of all measurements either photographically or in a log.

### III. Monitoring Requirements and Monitor Calibration

Stations are required to comply continuously with certain operating requirements such as frequency, modulation, and antenna pattern. The measurements must be done often enough to insure that the station is always in compliance. Originally, to satisfy this requirement, early trans-

mitters required continuous monitoring of frequency and modulation. Today, transmitter stability has improved to the point that this is no longer required. Directional stations check the antenna pattern every three hours, and verify with a field strength meter once a month. Non-directional stations monitor antenna current and calibrate the remote meters at least once a week.

The purpose of this section is to discuss techniques for double checking or calibrating the station monitoring equipment. Frequency measurements are also discussed.

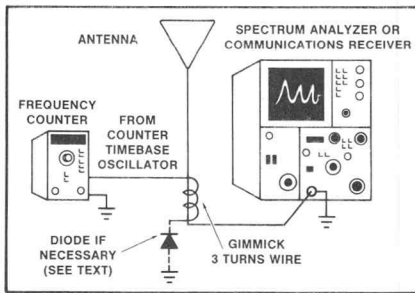
#### A. Frequency

An actual frequency monitor is no longer required by the F.C.C. Instead, it is up to the chief engineer of the station to use any means to insure that the station carrier is kept within  $\pm 20$  Hz of the assigned frequency. This must be measured at least once each calendar month (§73.59, 60).

A number of choices exist, depending upon the equipment available. A frequency monitor might still be used and is certainly recommended for day-to-day verification. However, the frequency counter is almost universally accepted as the test instrument used for the monthly calibration. The only problem is the verification of the frequency counter accuracy with the National Bureau of Standards. This can be done by sending the counter to a calibration service center or by using one of the following techniques.

##### Direct Comparison Measurement Technique

This can be used on most frequency counters containing a 1 or 5 MHz internal reference oscillator. A receiver or spectrum analyzer is used to monitor WWV, WWVB (60 kHz), WWVH, or WWVL<sup>10</sup>. A small portion of the frequency counter time base oscillator signal is coupled into the receiver as shown in figure 23. After the station (usually WWV at 5, 10, or 15 MHz) is carefully tuned in on the receiver, the frequency counter oscillator or harmonics of the oscillator are zero beat against the in-



**Fig. 23.** Direct Comparison Technique for Frequency Calibration

coming signal.

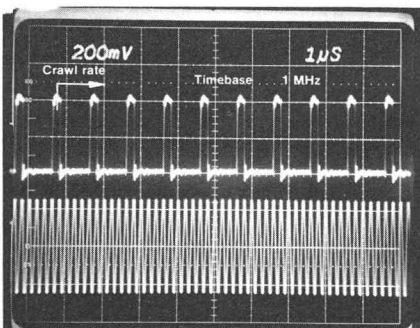
This technique is simple, although its accuracy is based upon two factors. The ability to detect a zero beat on a communications receiver may be limited to  $\pm 20$  Hz because of the lower audibility limits. The spectrum analyzer, however, can be used in ZERO SPAN to make an oscilloscope display an absolute zero beat.

Sometimes, when using a higher WWV frequency, such as 10 or 15 MHz, it is difficult to obtain enough harmonic energy to zero beat. A diode across the counter time base output test point will cause rich harmonics if enough drive cannot be obtained by other means.

#### Oscilloscope Comparison Technique

This technique uses a dual trace oscilloscope to display the counter time base, compared to the NBS standard. The technique can be used to compare almost any standard time base to any of the NBS services, even if the frequencies are different. For example, the 5-, 10-, or 15-MHz WWV transmission can be directly compared to a 1-MHz time base.

To use the technique, the frequency



**Fig. 24.** Oscilloscope Comparison of 5 MHz WWV against 1 MHz Time Base

counter time base oscillator should be connected to one input on a dual-trace scope. The NBS signal should be connected to the other input. The NBS signal can be obtained from a specially built receiver, from a test point in the rf chain of some communications receivers, or from a transfer or crystal oscillator zero beat against WWV.

The oscilloscope time base should be triggered on the WWV standard. By using the 1  $\mu$ s/DIV sweep speed, movement of the counter time base display across the (figure 24) screen in more than one second is equivalent to  $1 \times 10^{-6}$  accuracy. The counter time base should be adjusted until  $10^{-6}$  accuracy is achieved.

#### B. Modulation

Stations are required to have, in constant service, a type-approved modulation monitor (§73.56). This monitor should be periodically inspected and calibrated. The oscilloscope has long been accepted as a reference for calibrating monitors. However, with the advent of positive peak or super modulation<sup>11</sup>, monitor calibration is no longer a simple procedure. The spectrum analyzer does have the capability to verify many of the parameters associated with positive peak modulation, including monitor calibration verification. The spectrum analyzer can also measure low level modulation very accurately. A complete description of positive peak modulation and its characteristics are presented on page 17 of this booklet.

Presented below are two simple procedures for calibrating monitors with the spectrum analyzer.

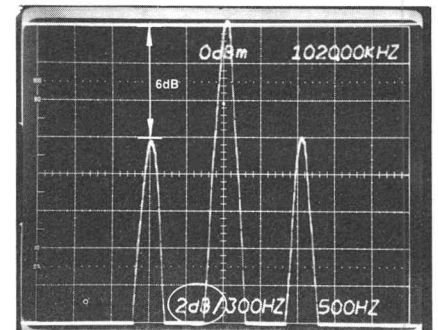
#### Calibration of the Amplitude Modulation Monitor

The monitor may either be removed from service or checked quickly during the experimental period.

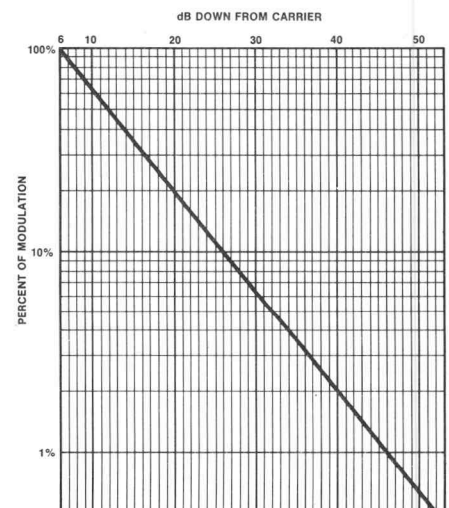
1. Connect an audio oscillator such as the SG 502 through the main console or through an attenuator into the transmitter. If the monitor is removed from service, a cw generator capable of being

cleanly modulated should be employed.

2. The spectrum analyzer (7L12 or 7L5) should be bridged across the rf line feeding the modulation monitor. Caution—auxiliary pads may be necessary to protect the spectrum analyzer input.
3. A 1000-Hz tone should be selected on the SG 502 audio oscillator. The tone should be increased in amplitude until the two 1000-Hz sidebands on the spectrum analyzer as exactly 6 dB down from the carrier. This is equivalent to 100% modulation (figure 25).
4. The sidebands should be inspected for harmonics. Any harmonics less than 26 dB down (at 10 dB/DIV) from the 1000-Hz sidebands indicates distortion greater than 5% and will cause inaccuracy in the monitor calibration.
5. Assuming the harmonic content is less than 5%, the modulation



**Fig. 25.** 100% Modulation Indicated by 1000 Hz Sidebands



**Fig. 26.** Chart of dB vs % of Modulation

monitor should be set to indicate 100% on both positive and negative peaks when the analyzer indicates 100%.

- Other amounts of modulation less than 100% should be checked to verify that the monitor tracks at lower modulation levels. The chart in figure 26 gives some common values of percent vs dB down of the sidebands.

#### Alternate Technique for Measuring Amplitude Modulation

Another technique especially useful for calibrating positive-peak modulation monitors, and accurate for all calibration, included the use of the ZERO SPAN and LIN display mode. When the spectrum analyzer center frequency is tuned to the station, no modulation will be indicated by a horizontal line. As modulation is applied, a sine wave will appear.

By positioning the zero modulation line on the center graticule line with the red GAIN control, modulation levels of 25%, 50%, 75%, and 100% will appear as shown in figure 27.

Again, with zero modulation, use the VERT POS control to set the line on the third graticule line as shown in

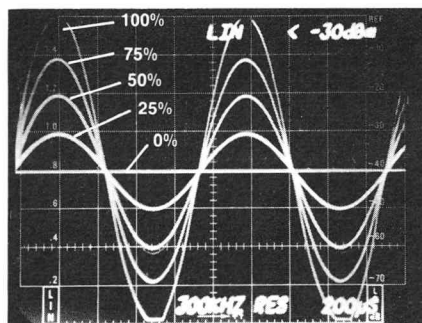


Fig. 27. Modulation Levels of 25%, 50%, 75%, and 100%

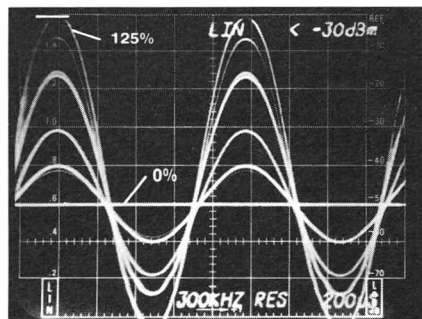


Fig. 28. Positive Peak Indication to 125%

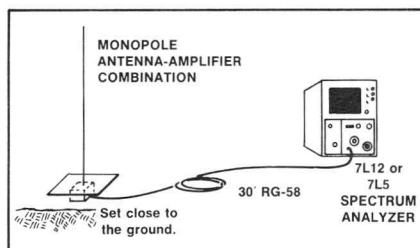


Fig. 29. Connecting the Monopole to the Spectrum Analyzer

figure 29. Positive-peak modulation of 25%, 50%, 75%, 100%, and 125% can then be indicated as shown.

#### C. Antenna Patterns

All **am** radio station antennas have characteristic radiation patterns. Directional stations must be checked using a field strength meter at 30-day (or less) intervals. The techniques described below are not intended to take the place of a field strength meter, but may be useful as a means of verification, or in emergency situations, such as when a field strength meter is in for repairs. In addition, many nondirectional stations require field strength readings to determine service area or ground conductivity. If a field strength meter is not available, the spectrum analyzer technique described below may be used. This technique is particularly useful when doing an interference study since both the field strength and level differences between stations will be indicated on the analyzer screen. A preamplified monopole antenna is quite easy to construct and use for broadcast band and harmonic measurements. It has the advantage of reading directly in  $\mu\text{V}/\text{meter}$  with no correction factors. The calibration is directly related to antenna theory. Therefore, the antenna has a natural calibration value and does not require calibration by a laboratory in an antenna field.

The final advantage of the antenna specified is that it provides direct  $\mu\text{V}/\text{meter}$  readings at any frequency up to 20 MHz. This makes it possible to measure harmonics in field strength relative to the station carrier.

**NOTE:** This procedure for measuring field strength will not be accepted by the F.C.C. as the rules are presently written.

To make field strength readings using 7L12 (or 7L5) Spectrum Analyzer and the monopole antenna shown.

- Calibrate the 7L12 (or 7L5) Spectrum Analyzer carefully using the internal calibrator signal. The accuracy of the calibration determines the overall accuracy.
- After arriving at the site at which the measurement is to be made, connect the antenna and tune in the station on the analyzer. Any span may be used to display either the single station or adjacent stations.
- Hold the monopole vertically and read, as accurately as possible, the signal level indicated on the analyzer in dBm.
- Using the dBm to  $\mu\text{V}/\text{meter}$  chart (figure 30), convert the dBm value to microvolts/meter. A complete example is shown in figure 31. When using the 7L5 Spectrum Analyzer, readings directly in microvolts can be obtained in the LIN mode so that no conversions are required to obtain  $\mu\text{V}/\text{meter}$  readings with monopole recommended. See figure 32.

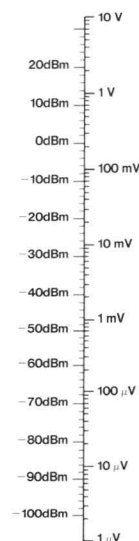


Fig. 30. dBm to Microvolts Chart

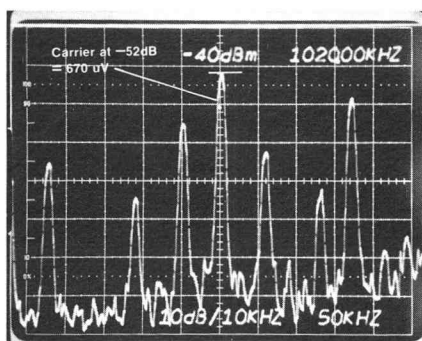


Fig. 31. Measurement and Example of Field Intensity Measurement

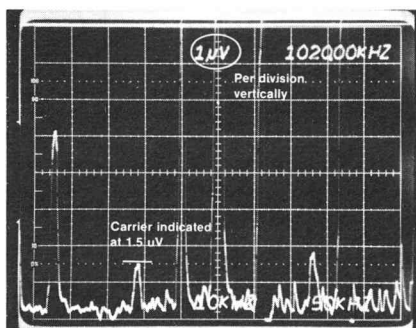


Fig. 32. Measurement Directly in Microvolts on the 7L5

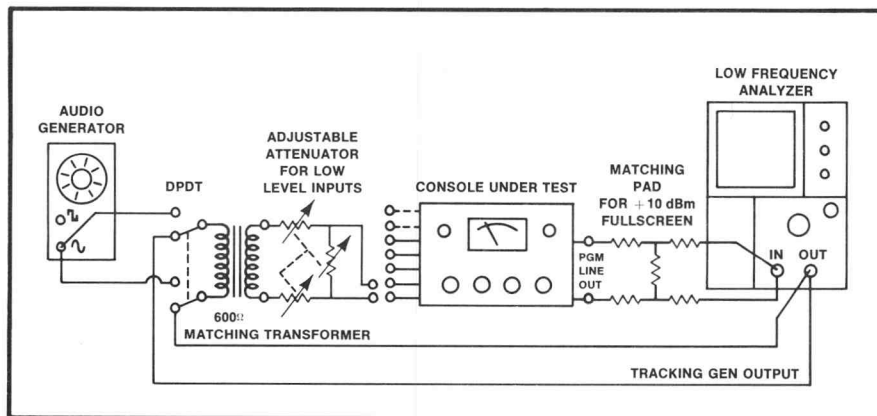


Fig. 33. Hookup for Audio Console Checks

## IV. Day-to-Day Measurements

Day-to-day measurements often tend to fall into the category of "fix it when it breaks" with little done in the area of preventive maintenance. We would all like the time to squeeze every extra ounce of performance out of a piece of equipment; however, time works against us.

Presented below are techniques that *rapidly* check various parts of the audio chain. All of these techniques use the 5L4N low frequency or audio Spectrum Analyzer and an audio oscillator such as the SG 502.

### A. Console Checks

This is a test procedure that checks the response, distortion, and noise on each input of an audio console. By using the switch and jumper

cable arrangement shown in *figure 33*, it is possible to test each input quite rapidly.

1. Connect the program line OUT on the console through a matching pad to the input of the 5L4N Spectrum Analyzer.
2. Connect the switch harness (alligator clips are recommended) to the first input on the console and select a level that does not over drive the console as indicated by the console vu meter.
3. Use the 5L4N Tracking Generator to sweep the console from 20 Hz to 20 kHz.
4. Switch to the SG 502 Audio Oscillator and drive the console to 0 vu using a 1000-Hz tone.
5. Check the harmonic distortion using the technique and charts on page 6 for both the combination of low audio oscillator output with the console pot set to 3/4, and high oscillator output with the console pot set to 1/4. Both of these tests should still

indicate 0 vu.

6. Check the low level harmonic distortion by setting the console pot to 1/2, and turn down the audio oscillator output until the vu meter on the console indicates -13 dBm.
7. Switch off the audio oscillator and read the residual noise and hum for that channel of the console using the procedure on page 8 of this booklet.
8. Continue response, harmonic distortion, and noise tests on all inputs of the console.

### B. Turntable Checks

Turntables should be periodically checked for speed, wow, and flutter (both mechanical and electronic), and equalization, and stylus-cartridge performance.<sup>12</sup> Speed may, of course, be checked with a strobe disc. However all of the other parameters may be checked quickly using the low frequency spectrum analyzer and readily available test records.<sup>13</sup> You may wish to combine these tests with the console checks to save time.

1. Connect the 5L4N Spectrum Analyzer to the output of the console on the program line. If the turntable is not connected to a console, the 5L4N should be connected to the cartridge preamplifier output.
2. A test record<sup>14</sup> such as the NAB monophonic-stereo 12-5-93 should be used. Select the highest frequency band available (10 kHz preferred) and watch the output display with the 5L4N Spectrum Analyzer set for a span of 20 Hz/DIV. Horizontal instability of the display is produced by wow and flutter and can be measured by noting the frequency variation:

Percentage of W & F =

$$\frac{\text{Deviation frequency}}{\text{Test Frequency}} \times 100$$

3. Again, use the test record and sweep the 20 Hz to 20 kHz log span. Use the store mode of the mainframe to store each sweep, and sweep the span a number of

times until a flat response curve is built up as shown in *figure 35*. If a problem is noted, the electronics can be swept by using the tracking generator output of the 5L4N. The response curve for the electronics will roll off due to R1AA equalization. If a sweep is not available, a discrete tone response test can be used in the same manner.

4. Noise can be checked by selecting a "quiet" band on the test record and displaying the spectrum from 0 to 20 kHz on the audio spectrum analyzer. Low frequency rumble, hum, and noise may all be detected. The signal to noise ratio may be measured using the technique described on page 8 of this booklet.
5. Cartridge performance is especially dependent upon the tracking pressure. While manufacturers recommend stylus pressure, the exact pressure may be verified by using the Two-Tone glide Intermodulation (**im**) Distortion<sup>15</sup> band on the test record. Display the two tones (4000 Hz and 5000 Hz) on the 5L4N Spectrum Analyzer.
6. As shown in *figure 36*, the stylus pressure should be adjusted until the sidebands 1000 Hz above and below the two tones are at a minimum amplitude. If this test is performed when a stylus is new and the dB down of the sidebands recorded, this figure may be used to indicate stylus wear. The **im** distortion should typically be 50 dB or more below the two tones. Anti-skate and damping adjustments may also be set using this technique.

### C. Cartridge and Tape Machines

The cartridge and tape machine have become standard equipment in all stations. Automated stations rely entirely on program material via the tape medium. While many machines will run virtually forever, quality reproduction requires almost continuous maintenance, lubrication, head cleaning and degaussing, transport adjustments, and head and

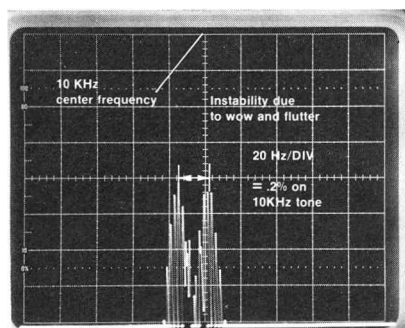


Fig. 34. Wow and Flutter Measurements

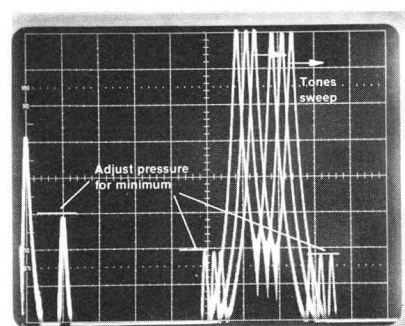


Fig. 36. Two-Tone Glide Tracking Test

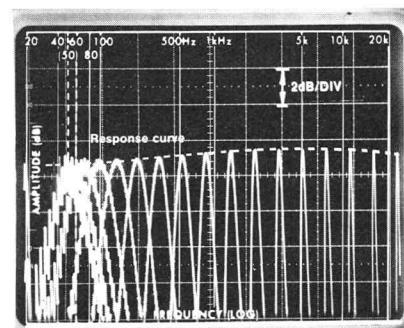


Fig. 35. Flat Response from RIAA Equalization

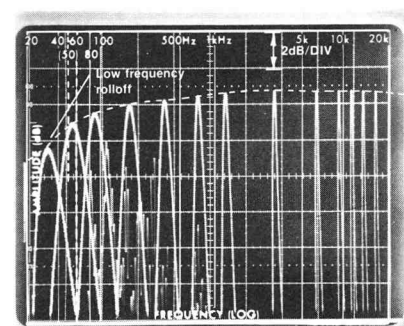


Fig. 37. Frequency Response of a Cart Machine

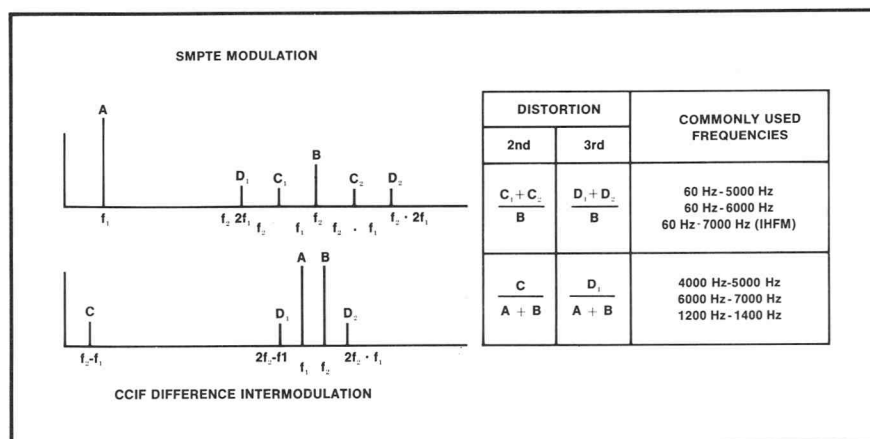


Fig. 38. The Two Common **Im** Distortion Test Standards

electronic adjustments.

The primary measurement<sup>16, 17</sup> requirements are frequency response, signal to noise, standard output level, distortion, and wow and flutter. By using standard NAB or other test tapes produced by a cartridge machine manufacturer, it is possible to rapidly evaluate machine performance, make minor adjustments, and return machines to service in very short order.

It should be standard practice to evaluate the playback circuitry us-

ing test tapes to insure that this portion of the machine is operating correctly before troubleshooting the record circuitry.

#### Procedure for Cart and Tape

1. Connect the 5L4N Spectrum Analyzer to the LINE output of the tape or cartridge machine. The 5L4N may also be connected to the console PROGRAM OUTPUT LINE so that the tape and cart tests may be performed at the same time as the console and turntable tests.

2. The tape or cart machine performance should be checked using an NAB standard test tape for standard reference level. For reel-to-reel tape machines, the test tape is designated NAB 65, preceded by the speed desired (7½, 15 ips, etc).<sup>18</sup> For cartridge machines, the test tapes are designated NAB #1 through #4. The Standard Reference Level test track should be played to determine if the program line output is at the level specified on the test tape. A low level output indicates a number of possible problems: weak playback electronics, head alignment, dirty or worn heads, etc.
3. Head azimuth should be checked by playing the azimuth test track (usually 15 kHz) and rocking the heads for maximum output.
4. Frequency response should be checked by using the response test tone tracks and the storage mode of the 5L4N Spectrum Analyzer. A display similar to *figure 38* will be obtained from the test tones. Playback equalization should be adjusted if response problems are indicated.
5. Wow and flutter should be tested by using the 3-kHz test track indicated on the test tapes. The tone should be displayed at 20 Hz/DIV span on the 5L4N. The deviation indicated by horizontal jitter or variation represents wow and flutter. A movement of 1 division equals 0.6% of wow and flutter. Higher resolution can be obtained by using the 15 kHz azimuth test tone. In that case, a jitter or variation of 1 division equals 0.13%. Another way to calculate wow and flutter is to measure the jitter or deviation in frequency and divide this by the test frequency.

$$\frac{\text{Deviation Frequency}}{\text{Test Frequency}} \times 100 =$$

% of Wow and Flutter

The NAB recommends that 0.1% is acceptable for reel-to-reel machines and 0.2% is acceptable for cartridge machines.

6. Signal-to-noise ratio of the play-

back system should be checked with the playback electronics set for normal operation and the transport stopped. The signal-to-noise ratio is measured as the dB range between the Standard Reference Level and the noise floor of the display at 3 kHz bandwidth, as described on page in the signal-to-noise section of this booklet.

7. The record electronics should be checked by using an audio oscillator such as the SG 502. Thread a clean, high-quality tape on the machine being tested and record a 400-Hz tone with 0 vu indicated on the cart or tape machine. When the tone is played back, it should indicate the same level as a Standard Reference Level tape.
8. Record azimuth should be set by using a 15-kHz tone in the record mode. The record head should be rocked for maximum output while monitoring with the playback head.
9. The frequency response should be adjusted by using the tracking generator output of the 5L4N while monitoring with the playback head. Because of the delay between the record and playback head, it is necessary to use a slow sweep mode in the 20 Hz to 20 kHz LOG SPAN MODE.
10. Signal-to-noise ratio should be checked through the entire record playback systems by terminating the INPUT in 600 ohms. The noise should be measured with the tape in motion, first in the playback mode, then in the record mode. A difference of more than 3 dB generally indicates noisy record electronics or level problems.
11. Harmonic distortion of the entire record playback chain can be measured by inserting tones from an audio generator. The distortion can be calculated as shown on page of this booklet. Distortion indicates excessive bias, bad tape-to-head contact or defective electronics.

## D. Intermodulation Distortion

Intermodulation distortion is determined by putting two or more pure tones through an amplifier and measuring the amount of each tone that is transferred (cross modulated) on to the others.

While the F.C.C. makes no references or recommendations concerning intermodulation in **am** radio, it is recognized by many that harmonic distortion tests do not tell the entire story.<sup>19</sup> Music is composed of complex tones. Harmonic distortion tests are performed using single tones.

Studies performed many years ago, by the Society of Motion Picture and Television Engineers (SMPTE), proved that a correlation exists between actual listening tests and **im** distortion. This correlation was much higher than for harmonic distortion tests. Hence, the SMPTE has used the **im** distortion tests for motion picture film for years.

Most broadcasters are in the music business where **im** distortion tests would prove valuable. It is a welcome fact, then, that the audio spectrum analyzer is capable of measuring both **im** and harmonic distortion.

The following procedures may be used to measure **im** distortion by either of two techniques, the SMPTE or the CCIF.<sup>20</sup> The exact details and options for these two tests are shown in *figure 39*. Procedures are shown for testing the transmitters; however, any of the studio equipment may be also tested for **im** distortion. While both tests are standardized around higher frequency audio tones, the lower frequency cutoff of **am** transmitters makes it desirable to use lower frequency tones. We recommend that 60 Hz and 5 kHz be used for the SMPTE method and 4- and 5-kHz be used for the CCIF method.

### Procedure for Intermodulation Distortion Tests

1. Set up a two-tone source connected to the input of the console or the transmitter as shown in *figure 39*. If the two audio generators are not available, a filament transformer can be used for a 60-Hz tone. If this is done, however,

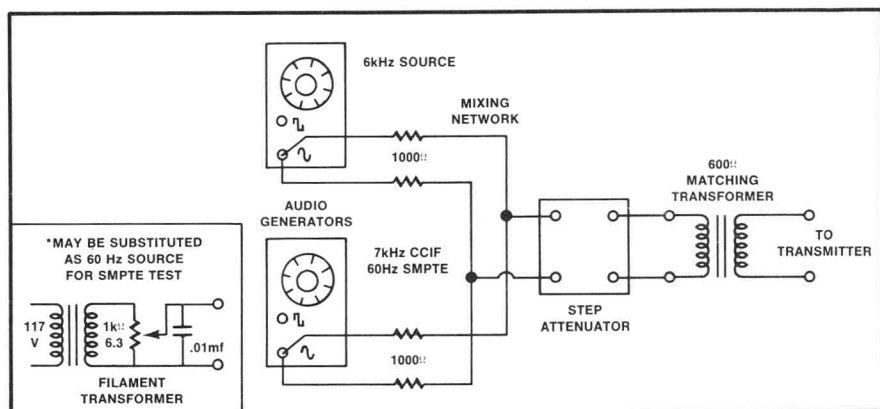


Fig. 39. Im Distortion Equipment Setup

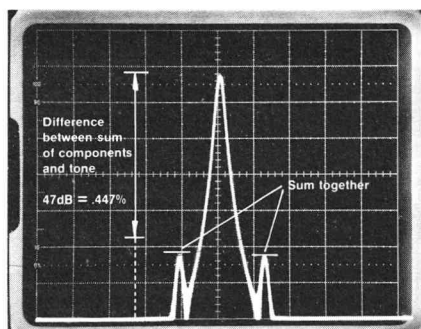


Fig. 40. SMPTE Test Results

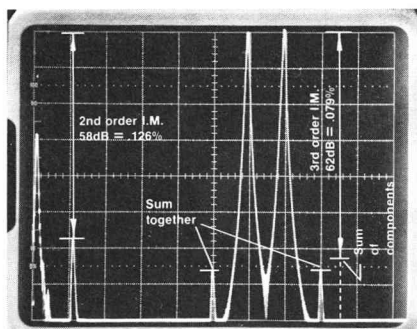


Fig. 41. CCIF Test Results

the SMPTE technique must then be used.

- Set the tone ratio. If the SMPTE method is used, the 60-Hz tone should be four times (12 dB) greater than the 5, 6, or 7 kHz tone. If the CCIF technique is used, the two tones should be equal in amplitude.
- The console or transmitter input should be increased until 100% modulation (0 vu) is indicated.
- The 5L4N should be connected to the modulation monitor or detector output and set for span of 0 to 10 kHz.
- SMPTE distortion is measured by noting the dB down of the 60-Hz sidebands from the 6-kHz tone, as shown in figure 40, then converting to percentage using the chart in figure 10.
- Im distortion measurement using the CCIF technique is performed by noting the dB down of the generated 1-kHz offset sidebands or 1 kHz tone (as shown in figure 41) then converted to percentage

using the chart in figure 10. (Sum the component values to obtain true im distortion for the 3rd order distortion.)

### E. Transient Intermodulation Distortion

Transient Intermodulation (**tim**) Distortion is amplifier distortion that occurs principally during loud (high level), high frequency passages. Most music contains some material that can cause **tim** distortion. Amplifiers with large amounts of negative feedback are prone to **tim** distortion because the amplifier loop, if improperly designed, requires too much time to respond to rapid transients.<sup>21</sup>

Since the introduction of the transistor power amplifier, the "transistor sound" has been discussed. Even though, in many cases, a transistor amplifier tested better in terms of distortion than a tube counterpart, during a listening test the tube unit would unmistakably perform better. **Tim** distortion is one explanation of

these discrepancies. Transistor amplifiers perform excellently in tests using steady-state harmonic and intermodulation tests. However, music material generates amplifier distortion because of its transient nature.

A popular explanation for the source of **tim** distortion is that the transients reach or exceed the slew rate of the amplifier, causing an instant, severe intermodulation condition until the time lapse of the negative feedback signal overcomes and corrects the distortion. Applying this explanation to the **am** station, we have all heard an old transmitter that sounded a lot better than a more recent high powered one, *even though* the new transmitter tested better on the harmonic distortion tests. The key factor is the use of high negative feedback. While transistors are still in the future for super power transmitters, the broadcaster has been using large amounts of negative feedback normally associated with transistors to correct high power tube type modulation output stages. Many transmitters detect the **rf** and apply feedback to the first audio stage.

**Tim** distortion does not occur in the feedback loop, but when the signal is delayed in the forward direction. A number of factors contribute, such as mechanical length (often 8 or 10 feet through the transmitter cabinets) and by-passing, in the audio stages, to stop oscillation and **rf**. Cases of 60% to 70% of **tim** distortion have been found in transmitters that passed F.C.C. harmonic distortion test standards.

Once again, the audio spectrum analyzer may be used to check **tim** distortion along with **im** distortion and harmonic distortion. No measurement standard exists in any industry yet for **tim** distortion; however, a low-frequency square wave with a high-frequency sine wave can produce easily interpreted results. Following is a technique that used a 6250-Hz sine wave and a 500-Hz square wave to yield a figure in percent of **tim** distortion. Also included are some notes on possible cures for this distortion, as observed by the author.

1. Connect the equipment as shown in figure 42. Two SG 502 Audio Generators must be combined as shown, one to produce 500-Hz square waves, the other to produce 6-kHz sine waves. An FG 501 may be substituted for the square-wave source. (The square wave should have excellent symmetry.) Connect the combined generators to the audio input of the transmitter.
2. Temporarily connect the oscilloscope portion of the audio spectrum analyzer (5L4N) to the combined output of the two generators and set the ratio of the square wave to sine wave at 5:1. A pattern similar to figure 43 should be obtained. This is the **tim** distortion "stock" signal.
3. Reconnect the audio spectrum analyzer to the modulation moni-

tor output (B) and display a span from 0 to 10 kHz.

4. Look for 500 Hz sidebands on the 6.25 kHz tone in the positions noted in figure 44. If these sidebands were 3 dB below the 6.25 kHz tone, 100% **tim** distortion would be indicated. To calculate actual **tim** distortion measure the sideband amplitude relative to the 100% modulation point (6 dB down from the 6.25-kHz tone) in dB. Convert dB to percentage using the chart in figure 10.

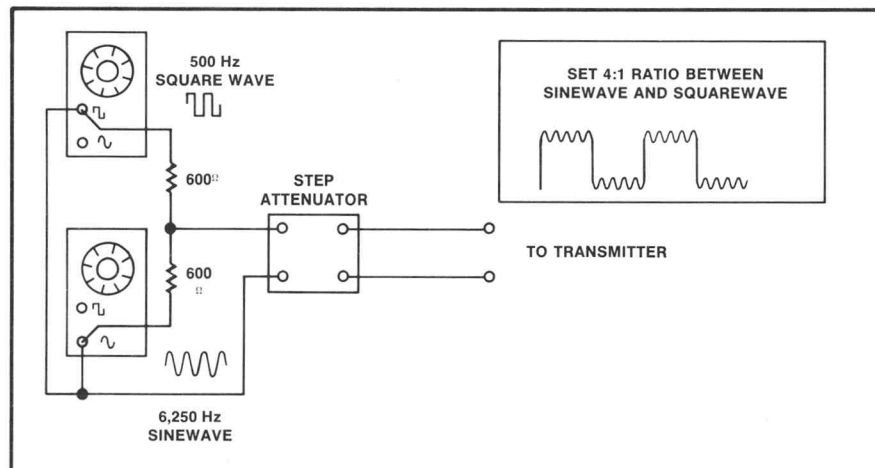


Fig. 42. **Tim** Distortion Equipment Setup

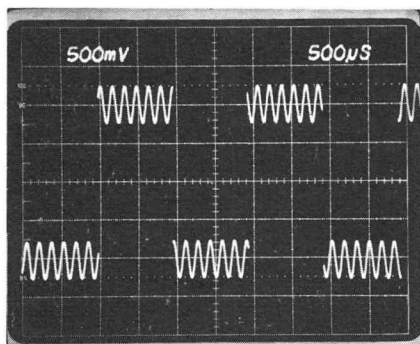


Fig. 43. **Tim** Distortion Stock Signal

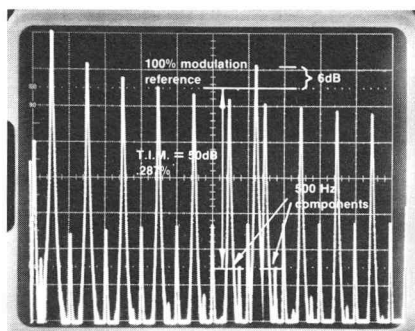


Fig. 44. **Tim** Distortion Test Results

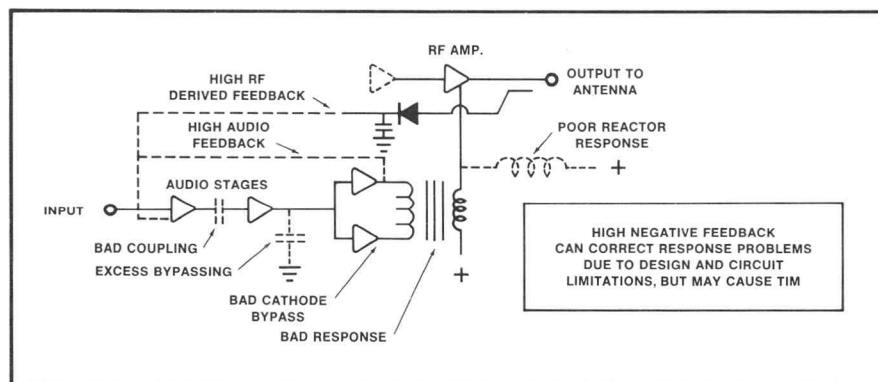


Fig. 45. Common Areas that Contribute to **Tim** Distortion Problems

**NOTES:** The largest factors contributing to **tim** distortion problems in transmitters can be traced to the use of large amounts of negative feedback. Since feedback corrects steady tone distortion, reducing feedback in the transmitter must be accompanied by other changes. Sometimes, the simplest cure is to temporarily remove the feedback connection and re-bias the audio and output stages for better performance. This will, of course, reduce the tube life on some stages, but once the feedback (and less of it) is reconnected, the transmitter will sound better. Another thing to check carefully is that the signal path bypass capacitors are not pulling down the response in the audio range.

In rare instances, the entire feedback loop must be divided so that each stage has a small feedback loop. Figure 46 points up some common contributing factors of **tim** distortion.

**CAUTION:** Modifying a transmitter can invalidate the type-approval. Any changes to a transmitter should be filed with the F.C.C.

## F. Positive Peak Modulation Characteristics

**Am** theory is simple for sine wave modulation; however, when a transmitter is modulated with music and voice material, certain peculiarities must be dealt with. Music and voice material seldom generate symmetrical waveforms. An **am** transmitter has some latitude in the positive modulation direction; however,

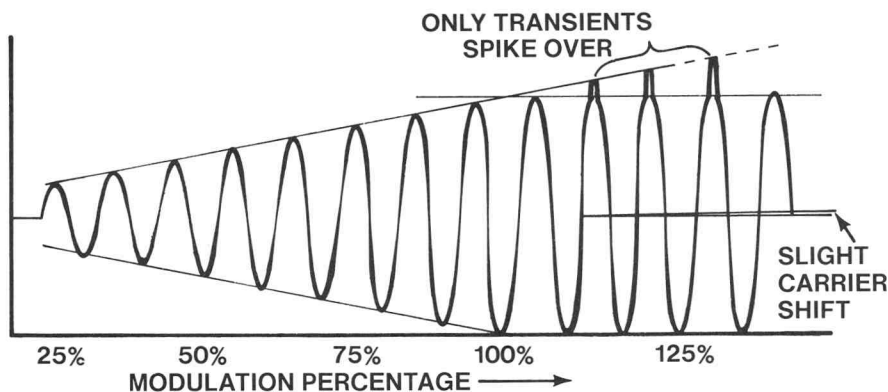


Fig. 46. Transmitter Characteristics for 125% Transient Response

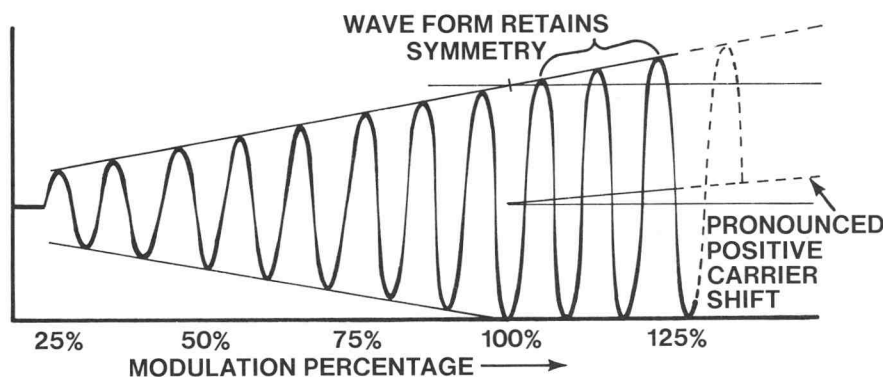


Fig. 47. Transmitter Equipped for 125% Super Modulation

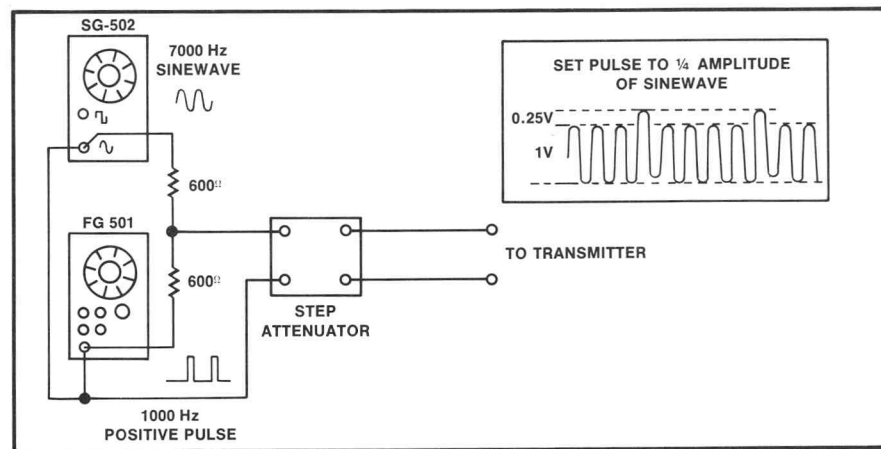


Fig. 48. Generator Connections for Transient Tests

negative modulation has a distinct limit of 100%. Clipped negative peaks results in distortion.

The present F.C.C. rules (revised in 1972) governing the **am** broadcast band permit a maximum of 100% modulation in the negative direction and an absolute maximum of 125% in the positive direction. If music could be predicted to always have nonsymmetry in one direction, then it could be transmitted and modulated over 100% positive with no

distortion.

Unfortunately, music and voice material is unpredictable and there can be just as much likelihood of a peak going positive as negative. Some elaborate devices such as the Frese Auto Pilot have been especially designed to sense nonsymmetry and invert the program material so that all peaks go in the positive direction, giving a station some headroom and increasing the sense of loudness. This scheme

probably represents what the F.C.C. had in mind by permitting positive peak modulation.

However, there is another interpretation not prohibited in the present rules. Some stations limit heavily in both the positive and negative direction, and then swing the carrier power up (positive carrier shift) on loud or transient passages. This can give a station of 1000 watts an effective power of 1265 watts and a greater apparent service area than normally operating stations.

However, there is a very fine line (not yet interpreted by the F.C.C.) between positive peak modulation, and substantial positive carrier shift. Normally, carrier shift must be held to a minimum of  $\pm 5\%$ . By permitting 125% instantaneous positive peaks, the F.C.C. is permitting positive carrier shift in excess of  $+5\%$ . Some further clarification is needed to define how much time (percentage of time) carrier shift will be permitted before a station is in violation for positive carrier shift.

Whether the rules have been interpreted correctly or not, both kinds of stations exist using 125% positive peak modulation and some means must be devised to check their performance and distortion. In addition, the modulation monitors must be accurately calibrated. The means by which the operator monitors positive peak is left to the discretion of the engineer; however, absolutely no modulation peak over 125% is permitted.

#### Procedure for Checking Am Transmitter for Positive Peak Capability

This test is designed to evaluate the capability of a transmitter to pass 125% positive peak modulation of a transient nature. This assumes that the transmitter will then be used with some form or correction that agcs or limits the negative peaks to 100% and permits the positive peaks to go to 125%. Some form of symmetry sensing and reversing device such as the Frese unit could also be considered for use ahead of the transmitter.

Most older transmitters are capable

of handling positive peak transients even though the stages are ac coupled. However, long duration transients will shift the audio envelope causing negative peak clipping. The test shown below uses a special test signal with 125% pulse material of short duration so that the effective envelope shift is less than 2% negative.

1. Prepare a test signal using a sine wave generator such as the SG 502 and a pulse generator such as the FG 501. Combine the two signal sources through two 600 $\Omega$  resistors as shown in figure 48. Using an oscilloscope, set up a 7000 Hz sine wave with a 1 kHz pulse riding upon the peak as shown in figure 49. The sine wave should be 1 volt pp and the pulse should be 0.125 volts pp.
2. Connect a spectrum analyzer such as the 7L5 or 7L12 to an rf test point and tune in the carrier. Then go to the zero span, LIN modes, and place the carrier line on the center graticule line using the CAL IF GAIN CONTROL.
3. Feed the test signal into the transmitter input, bypassing all processing equipment. Increase the input level until modulation is indicated on the spectrum analyzer. Make sure that the pulse in the test signal modulates the transmitter in the positive direction (upward deflection on the spectrum analyzer). If it does not, reverse the audio input polarity to the transmitter.

4. Increase the audio input level to the transmitter until 100% positive and negative modulation are indicated on the spectrum analyzer in zero span (refer to page 11 in this booklet for details on modulation measurements). Momentarily remove modulation and use the vertical position control to move the zero modulation reference line down one division. Reapply modulation and verify that the tip of the pulse extends one full division beyond the peak of the sine wave as shown in figure 49. Any indication less than a division indicates that the trans-

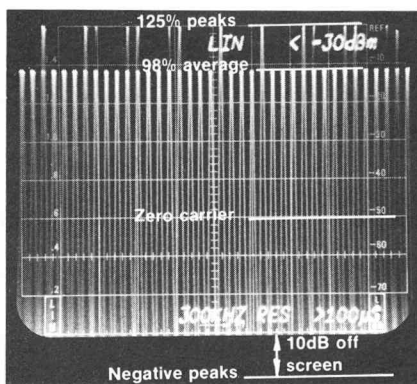


Fig. 49. Checking for 125% Positive Peak Response

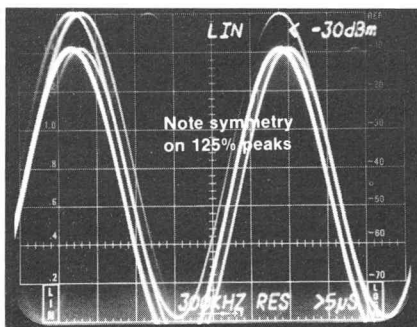


Fig. 50. Expanded Display of 125% Positive Peak to Test Symmetry

mitter cannot handle 125% positive peaks. Also note the symmetry of the 125% sine wave information by expanding the display with the sweep speed control to verify that there is no clipping (as in figure 50).

5. Most transmitters will handle 125% positive modulation in the low power position. This should be verified by recentering the spectrum analyzer display for low power and repeating steps 2, 3, and 4.
6. Assuming that the transmitter is found to be acceptable for 125% positive peak modulation, the modulation monitors should be checked to verify that it indicates the positive and negative peaks correctly.

#### Procedure for Checking Positive Peak Modulation Capability of Transmitters Equipped for Positive Carrier Shift

Smooth positive peak modulation is possible on some modern transmitters, particularly those utilizing pulse width modulation or phase modulation. These transmitters can

actually handle sine wave type material in excess of the normal 100% limits without distortion by effectively swinging up the carrier power.

The testing is very simple because pure audio sine waves can be used.

#### Procedure

1. Connect a spectrum analyzer to an rf test point on the transmitter and tune in the carrier.
2. Using the 2 dB/DIV MODE on the spectrum analyzer, note the carrier level for no modulation on the transmitter.
3. Insert a 1 kHz tone into the transmitter from an audio generator such as the SG 502.
4. Increase the level of the tone until the carrier level begins to increase. This point will generally occur somewhere between 85% and 100% modulation as indicated by the sideband to carrier ratio.
5. Continue to increase the level of the audio tone until the carrier increases exactly 1 dB from the reference point established in step 2. Simultaneously, the sidebands should be exactly 6 dB

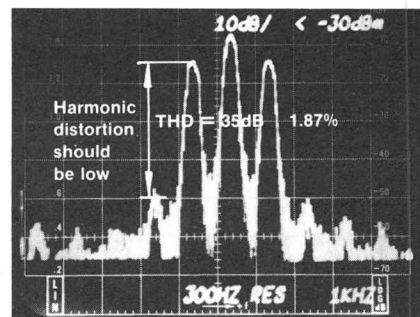


Fig. 51. Checking for 125% Modulation with Positive Carrier Shift

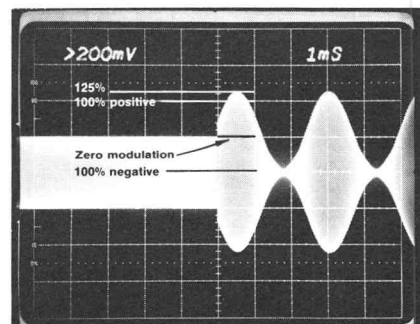


Fig. 52. Using an Oscilloscope to Test for Positive Carrier Shift

below the carrier signifying that 100% modulation of the carrier is occurring.

6. Harmonic distortion should be monitored as the 1000 Hz tone is increased by noting the ratio between the 1 kHz and 2 kHz sidebands. A complete description of the harmonic distortion measuring technique is given on page of this booklet. Harmonic distortion should stay below 5% (26 dB down combined sidebands) throughout the entire modulation range of the transmitter see figure 51).
7. These tests can also be monitored using an oscilloscope. The results are shown in figure 52.

#### FOOTNOTES

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3. "The F.C.C. Gives Perspective to Proof Requirements," Dennis Ciapura, *Broadcast Engineering*, Page 21, June 1973.
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5. "An Improved Method for the Measurement of Non-linear Audio Distortion," James S. Aagaard, IRE Transactions on Audio, Page 121, 1958.
6. "New AM Modulation Rules", Howard T. Head, *Broadcast Engineering*, page 32, January 1973.
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10. "Reference Data for Radio Engineers," Fifth Edition, Howard W. Sams and Co., © 1968.
11. "An Update on Super Modulation," Ron Merrell, *Broadcast Engineering*, Page 62, March 1971.
12. "NAB Standard Disc Recording and Reproducing," March 1964.
13. A complete list of test records is shown on page 33, March 1974, *Audio Magazine*.
14. Other records such as the CBS Laboratory STR-100 or 111 may be used.
15. RCA produces a special "Two Tone Glide" test record 12-5-105 especially for cartridge **im** tests.
16. "NAB Standard Cartridge Tape Recording and Reproducing," October 1964.
17. "NAB Standard Magnetic Tape Recording and Reproducing (Reel to Reel)," April 1965.
18. Available by writing to NAB, 1771 N. Street N.W., Washington D.C.
19. "Adding IM Tests to Your Audio Proof," Dennis Ciapura, *Broadcast Engineering*, Page 32, January 1973.
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